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1. INTRODUCTION

Advances in technology have increased the need for mechanical engineers with more complete knowledge and diverse skills than a typical undergraduate program can provide. As a result, graduates with a Master of Science in Engineering (MSE) degree can look forward to greater job opportunities, more rewarding positions, and higher levels of responsibility than engineers with just a Bachelor’s degree. Mechanical engineering, which is one of the broadest engineering disciplines, provides an excellent background for individuals interested in occupations ranging from product research and design to technological management. The Department of Mechanical Engineering and Applied Mechanics (MEAM) at the University of Pennsylvania has designed a flexible MSE Program to prepare students for professional careers and leadership roles in industry while also providing them with the opportunity to strengthen their fundamental knowledge and obtain an exposure to research. In recognition of the interdisciplinary nature of the modern workplace, students who enroll in our MSE program are encouraged to take courses in other departments in the School of Engineering and Applied Science, School of Arts and Sciences and the Wharton School of Business.

The information presented here is not exhaustive; students should also obtain information from the Penn Engineering website: www.seas.upenn.edu/graduate/handbook/index.php

More information, updated from time to time, on the MSE program is also available on the department website, www.me.upenn.edu/current-students/masters/pdf/mse-handbook-11.pdf. Reading all of the rules and procedures is essential in order to be familiar with various degree requirements and the plentiful opportunities that are available. These guidelines together with the above publications will answer most of your questions. Advice and answers to special questions may be obtained from your advisor or the Graduate Group Chair\(^1\), as well as the Graduate Program Coordinator\(^2\), who will assist you in any reasonable manner possible.

2. ADMINISTRATIVE STRUCTURE

The Graduate Group in Mechanical Engineering and Applied Mechanics administers the graduate program in MEAM. The Graduate Group is comprised of the primary faculty members of MEAM as well as faculty from other departments and schools throughout the University. This unique composition gives students the opportunity to work in emerging and interdisciplinary areas that are relevant to mechanical engineering. The current members of the MEAM graduate group and their research areas are listed in Appendix D. Additional information can be obtained from the department website.

All graduate programs in SEAS are administratively under the auspices of the Associate Dean for Academic Affairs\(^3\), whose activities with respect to graduate studies in MEAM are in conjunction with the recommendations of the MEAM Graduate Group Chair.

3. ADVISOR

The first person with whom a new student has contact is an assigned academic advisor. A program of study is developed with the academic advisor. Later on, if necessary, the student may request a change of advisor, which will be considered and approved by the Graduate Group Chair as appropriate. The academic advisor is responsible for monitoring the student's academic plan and, if applicable, thesis work.

4. DEGREE REQUIREMENTS

To earn an MSE degree in Mechanical Engineering and Applied Mechanics (MEAM), a student must complete 10 graduate level courses. Of the 10 courses, at least five must be MEAM courses, two must be mathematics, and the remaining three are electives. Three of the five must be selected from the preapproved core requirement list for the chosen concentration. The elective courses are typically in MEAM or other SEAS departments. Courses taken outside of SEAS should be relevant to the student’s career goals or to the subdiscipline of interest to the student. Up to two courses may be transferred from other institutions upon the approval of the Graduate Group Chair. The MSE degree can be completed in one year of full-time study. Students may take up to two independent study courses (MEAM 599). Independent study courses (MEAM 599) must follow the guidelines detailed in section 6 of this manual and may not be counted as part of the required five MEAM courses.

\(^1\)Dr. Jennifer R. Lukes, Room 247 Towne Bldg. (Tel. 215-898-3254, email: jrlukes@seas.upenn.edu)
\(^2\)Maryeileen B. Griffith, Room 297 Towne Bldg. (Tel. 215-898-2826, email: banford@seas.upenn.edu)
\(^3\)Dr. R. Vijay Kumar, Room 111 Towne Bldg. (Tel. 215-898-3630, e-mail: kumar@central.cis.upenn.edu)
The MSE concentration areas are:

- Robotics and Micro Electro Mechanical Systems
- Heat Transfer, Fluid Mechanics, and Energy
- Mechanics of Materials
- Biomechanics
- Design and Manufacturing

Opportunities are also available for students to customize their concentration with the guidance and approval of their academic advisor. The student and his/her academic advisor should agree upon a program of courses before the student embarks on his/her graduate study.

Appendix A lists the MEAM core, electives and mathematics courses for each concentration area.

### Summary of MSE degree Course requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math Requirement</td>
<td>2 ENM* Courses</td>
</tr>
<tr>
<td>MEAM Core Requirement</td>
<td>5 MEAM Courses</td>
</tr>
<tr>
<td></td>
<td>• 3 in concentration</td>
</tr>
<tr>
<td></td>
<td>• 2 any MEAM</td>
</tr>
<tr>
<td>Electives Requirement</td>
<td>3 Courses</td>
</tr>
<tr>
<td>Seminar Requirement</td>
<td>2 Semesters</td>
</tr>
<tr>
<td>(Full time students only)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10 Courses</td>
</tr>
</tbody>
</table>

5. GENERAL INFORMATION

Registration:
All students enrolled in a degree program are required to be continuously registered. Three courses per semester (including independent studies) is considered to be a normal full-time load for all students. Students in the MSE program may take up to five courses in a semester if they are in excellent academic standing (with a G.P.A. of 3.5 or better), with approval from the academic advisor and Graduate Group Chair. Part-time students usually take one or, at most, two courses per semester.

Leaves of Absence:
Continuous registration as a graduate student is required unless a formal leave of absence is granted by the Dean of Engineering.

Obsoleteness:
The maximum time allowed for the completion of all MSE requirements is seven years. Course units that are older than seven years may not be counted toward the degree requirements.

Changes in Course Program:
Students may add or drop courses without penalty during a semester if it is done by the deadline listed in the current graduate bulletin. The student must inform the advisor of the decision beforehand and receive his/her approval.

Grades, Credits, and Academic Standing:
The grading system is as follows: A (4.0), Excellent; B (3.0), Good; C (2.0), Fair; D (1.0), Poor; F (0.0), Failure. A course in which an F was obtained must be taken again; however, the F will remain on the student's transcript. Courses for which a passing grade was obtained cannot be retaken for credit.

An incomplete (I) or a no report (NR) are temporary notations and students are allowed a period of one semester to clear. Failure to clear an "incomplete" or "no report" within the allotted time will result in an automatic grade of F. No students will be permitted to graduate if there are any Incomplete, Unsatisfactory, or No Report notations on their records.

MSE students in Engineering are expected to maintain at least a B- average (2.7) in their work. A student whose record falls below a B- average will be put on academic probation and may be required to withdraw; graduation requires a B- average minimum (exclusive of thesis and dissertation grades).
6. INDEPENDENT STUDY

Independent study courses are important vehicles to accommodate special interests of the students that are not served through the regular courses. They create opportunities for mini-projects and a mentoring relationship between students and faculty. Independent study also can serve as a means students and faculty to lay a potential foundation for dissertation work prior to making a long-term commitment. The student should identify the topic and scope of the independent study in the semester prior to the one in which s/he intends to take on the independent study, and should identify a faculty advisor whose interests and expertise match the independent study topic.

Since independent studies are less structured than regular courses and typically do not come with strict deadlines, occasionally students tend to fall behind in their work. There is also the possibility of miscommunication between the student and the faculty on the objectives, extent, scope, and the grading method for the independent study.

The purpose of this policy is to set the rules for an independent study with the objectives of maintaining academic rigor and minimizing any potential for a miscommunication.

- An independent study course should require an effort comparable to that of a regular course, about 9 hours a week or a total of 126 hours per semester.
- The student should meet the faculty member administering the independent study (the advisor) on a regular basis, at least once a week. It is the student's responsibility to schedule these weekly meetings. Past experience indicates that failure to maintain regular contact with the student's advisor can lead to a less than satisfactory performance in the independent study course. The key to a successful independent study is a steady effort throughout the semester. The student should not expect to be able to cram a semester's work into a few days of intensive work at the end of the semester.
- Prior to the beginning of the semester in which the student contemplates taking the independent study, the student and his/her advisor should develop an independent study proposal. The first paragraph of the proposal should describe the objectives, scope, and content of the independent study. The second paragraph should state how the independent study will be evaluated and how the student will be graded. The document should be signed by both the student and his/her advisor, and it should be submitted to the Graduate Coordinator, who will convey it to the Graduate Group Chair for approval before the beginning of the semester.
- At the conclusion of the independent study, the student should prepare a brief report specifying what material was covered during the independent study, which objectives were met, and which were not. In the event that objectives were not met, a clear explanation should be provided as to why such objectives were not met. This document should also be signed by the student and his/her advisor, and it will be included in the student's file.
- It is the student's responsibility to make sure that these guidelines are followed. Failure to follow these guidelines may result in the student’s not receiving credit for the independent study.

7. POLICY ON TRANSFER OF CREDIT UNITS EARNED IN OTHER INSTITUTIONS

MSE students may obtain credit for up to two courses taken at another institution. These courses are referred to as transfer courses. Transfer courses must be graduate level courses in which at least a B grade has been earned. Transfer credit will only be considered for courses taken prior to matriculation in the graduate program in the Department of Mechanical Engineering and Applied Mechanics. To obtain credit for courses taken at other institutions, the following procedure must be followed:

- For each transfer course, obtain the course description and the title of the textbook used in the course.
- Identify a professor who teaches a similar course at Penn. If a similar course is not offered at Penn, identify a professor whose areas of expertise are in the general area of the course to be transferred. The professor should certify that the course is of similar level to a graduate course offered at Penn or, if a similar course is not offered at Penn, that the course qualifies for Penn students to take if it were offered here.
- Submit a petition on a standard form (Appendix C) to the Graduate Coordinator who will convey it to the Graduate Group Chair. Attach to the petition a copy of the transcript, the professor's certification, and documents and information noted in Appendix C.

8. MSE THESIS

The majority of MSE students complete an entirely coursework-based degree. There is also an option to complete a thesis-based MSE degree. This option is open only to top MSE students and is subject to availability of advisors with suitable research projects. Students pursuing this option typically take two years to complete the MSE. Students who elect to write a thesis cannot count independent study course units as a part of their 10 course units requirement, but thesis research credits (MEAM 597) may be substituted for up to three courses.
MEAM 597 is the course assigned to thesis/dissertation research. One, two or three units of this course of independent research may be undertaken simultaneously. The grading of MEAM 597 is done by the student's thesis advisor. Only grades of "S" (satisfactory), "U" (unsatisfactory) or "I" (incomplete) can be earned in this course. First year students must complete an advisor's sign-off form. This form may be found in Appendix E and should be submitted prior to registering for courses.

A full time MSE student who chooses to write a thesis must choose an advisor and a suitable thesis topic by the beginning of his/her second semester of graduate study. The advisor must be a member of the Mechanical Engineering and Applied Mechanics Graduate Group (see Appendix D). The Chair of the Graduate Group, in response to recommendations by the student and the student's advisor, will then appoint, at the latest by the middle of the student's second semester, a Thesis Committee consisting of at least two faculty members, one of whom shall serve as the Thesis Committee Chair. The thesis advisor may not serve as the Thesis Committee Chair.

Examples of a typical objective of an MSE thesis are:

- To advance the state-of-the-art in research.
- To solve new problems with existing tools.
- Development of a new instrument or measurement technique, or a computer program for analysis or advanced design.

The graduate student must submit a written thesis proposal and present it to the Thesis Committee by the end of the second semester of study, at the latest. The proposal should typically contain a statement of the objective of the work, a pertinent state-of-the-art review, the scope of the study, and an outline of the proposed final document. The Thesis Committee will evaluate the proposal and make recommendations on how it can be improved. The Chair of the Thesis Committee will then inform the Graduate Group Chair, in writing, about the Committee's evaluation of the proposal. The student must obtain the Thesis Committee's approval of the thesis proposal by the end of the student's second semester.

The thesis must be prepared and submitted following the general SEAS and University of Pennsylvania instructions. Instructions for preparation of the thesis can be found at: http://www.upenn.edu/VPGE/masters.html. When the thesis has been approved by the student's thesis advisor, a copy of the thesis must be given to each member of the Thesis Committee, who will then review it. The student must allow sufficient time for the review (at least two weeks). A public presentation of the work is then made; after this presentation, the Thesis Committee will give final approval or disapproval. The announcement of the presentation to the public must be submitted to the Graduate Coordinator for posting at least two weeks prior to the presentation.

All of the requirements of the thesis must be satisfied and approved before the thesis submission date specified by the Office of the Associate Dean for Academic Affairs. When final approval of the thesis is obtained, an original and a photocopy of the thesis must be submitted to the Associate Dean for Academic Affairs, 111 Towne Building prior to commencement, by the date specified. Both copies must be unbound and they must have original signatures. Additionally, a hardbound copy of the thesis (prepared according to instructions in Appendix B) must also be submitted both the Graduate Group Chair of Mechanical Engineering and Applied Mechanics and to the thesis advisor. Failure to follow the above schedule and requirements will result in a delay in awarding the degree.

9. TRANSITION TO THE Ph.D. PROGRAM

Those MSE students who are interested in pursuing a Ph.D. after the completion of their MSE degree program should petition the Graduate Group Chair with the request to take the exam.

Students who aspire to continue for the Ph.D. degree must maintain a GPA of 3.0 or above, and take and pass a qualifier exam, which serves as an important component of determining their ability to independently conduct research of high quality.

Complete details are available in the Ph.D. Guidelines.

10. ATTENDANCE AT DEPARTMENTAL SEMINARS AND THESIS PRESENTATIONS

The attendance of all full-time graduate students at departmental seminars is mandatory. There are many good reasons why students should attend departmental seminars even when the seminars are not directly linked to their areas of research. For example:

- The seminar provides an opportunity to learn about the state-of-the-art in MEAM.
- The seminar provides an opportunity for the student to get acquainted with people from other institutions and companies and get an inside view of the culture at other institutions. On more than one occasion, during job interviews, interviewers have been known to mention a visit to Penn and delivering a seminar. The student would like to be in a position to comment on
that particular seminar and state how enjoyable it was.

- The departmental seminars are an excellent opportunity to get together as a department. It is hoped that a full attendance at these seminars will help create departmental spirit and cohesiveness.

Seminar Course
The seminar course (MEAM 699) has been established so that students are recognized for their seminar attendance as well as to encourage students to attend. There are no quizzes, tests, or homeworks. The course is graded S/U. In order to obtain a satisfactory (S) grade, the student must attend more than 70% of the departmental seminars. For example, in a term in which 12 seminars are given, the student will need to attend at least 9 seminars to obtain a satisfactory grade. Participation in the seminar course will be documented and recorded in the student's transcript. In order to obtain their degree, MSE students will be required to accumulate 2 seminar courses. Under special circumstances, e.g., in a case of a conflict with a course offering, the student may waive the seminar requirement for the particular semester by petitioning to the Graduate Group Chair. Part-time students are exempted from the seminar attendance requirement although they are encouraged to attend the seminars.

11. SUBMATRICULATION
Outstanding undergraduate students at the university may submatriculate in the MSE degree program and take graduate-level courses as electives during their junior and senior years. After fulfilling the requirements of both programs, the student will receive a BSE and a MSE degree. Undergraduates at the University of Pennsylvania may double-count up to three graduate-level courses taken while enrolled as a submatriculant towards both the undergraduate and the graduate degree. The MSE degree may be completed in one to two semesters of study. In order to complete both degrees in only four and one-half years, students can consider:

- Taking independent study courses in the summer of the fourth year (up to 2 course units of study),
- Taking five courses in the final term,
- Taking extra graduate-level courses (cannot be counted towards the B.S.E. degree) during the undergraduate program.

Submatriculation application (http://www.seas.upenn.edu/undergraduate/advising/documents/ApplicationforSubmatricualtion.pdf) must be submitted by the end of the junior year.

12. DUAL DEGREE PROGRAMS
Dual Degree in Two Engineering Disciplines
Students may enroll in a dual degree program and receive an MSE degree in Mechanical Engineering and any of the other disciplines in the Engineering School such as Electrical and Systems Engineering, Bioengineering, Computer Science, Chemical and Biomolecular Engineering, and Materials Science and Engineering. The dual degree program requires the completion of at least 16 courses and satisfaction of the MSE requirements of each department in which the student wishes to major. This program typically requires four semesters to complete. To enroll in this program, the student must complete an application form, listing the course plan for both programs and obtain the approval from the Graduate Group Chair of each department. Applications for this program are available in the Academic Programs Office in 111 Towne Building.

MBA/MSE Dual Degree Programs
The Mechanical Engineering Department and the Wharton School of Business Administration are committed to the education of excellent managers and engineers who will contribute significantly to the challenges faced by industry. This program leads to two degrees: Master of Business Administration (MBA) and Master of Science in Engineering (MSE). Typically, the program requires 5 semesters of study. To participate in the MBA/MSE Dual Degree Program, the student must apply to, be accepted by, and meet all the requirements of both schools: the Graduate School of Business and the School of Engineering and Science. This requires separate applications to both schools.

13. SUMMER STUDIES
There are several possibilities for scholarly activities by graduate students at the University during the summer which include:

- Independent study and research (MEAM 599 or 597) with an instructor willing to act as a supervisor during the summer.
- Course work outside SEAS, as well as a limited number of regular courses occasionally offered by some SEAS departments. The advisor, in consultation with the Graduate Group Chair, must approve summer school courses.

Questions on summer session registration should be referred to the Graduate Coordinator.

14. RECORDS
The official graduate student records are kept in 111 Towne Building; transcripts can be viewed on Penn InTouch at https://sentry.isc.upenn.edu/intouch. Graduate students are encouraged to periodically check the accuracy of their records and to
bring any discrepancies to the attention of the Graduate Group Chair.

15. GRADUATE ENVIRONMENT

The size of the Department of Mechanical Engineering and Applied Mechanics fosters a close interaction between the graduate students and the entire faculty. Every effort is made to create an environment of scholarship, creativity and learning, which is the very essence of graduate study. This enhances the quality of student-faculty communications and enriches the academic environment to benefit both learning and discovery. The Department strongly supports the Mechanical Engineering Graduate Association (MEGA). MEGA is a student-run association that represents the entire graduate student community in MEAM, and organizes both social and technical events. A chosen representative of MEGA will be invited, if appropriate, to attend Graduate Group meetings to serve as a communication channel for information between the Graduate Group and students.
APPENDIX A

List of approved mathematics courses (all concentrations)

MATHEMATICS REQUIREMENTS

All MSE students are required to take at least two mathematics courses selected from the following list. Prior approval from the Graduate Group Chair is required if a student would like to take a course other than the ones listed below to satisfy the math requirement.

- ENM 502 Numerical Methods and Modeling
- ENM 503 Introduction to Probability and Statistics
- ENM 510* Foundations of Engineering Mathematics I
- ENM 511 Foundations of Engineering Mathematics II
- ENM 540 Topics in Computational Science & Engineering
- ENM 600 Advanced Engineering Mathematics
- ENM 601 Special Topics in Engineering Mathematics

* Recommended

4 ENM - Engineering Mathematics
List of approved courses for students concentrating in

**ROBOTICS AND MICRO ELECTROMECHANICAL SYSTEMS**

Ongoing effort in mechanical systems focuses on modeling and controlling dynamical systems, robotics, and micro electromechanical systems (MEMS). The graduate courses provide students with a firm theoretical foundation and the interdisciplinary experimental skills that are necessary for dealing with modern-day complex systems. Much of our work involves collaborations with, among others, the Departments of Bioengineering, Computer and Information Science, Electrical and Systems Engineering as well as the Wharton School of Business Administration.

**Preapproved Core Requirement Courses**

- MEAM 510 Mechatronics
- MEAM 513 Modern Feedback Control Theory
- MEAM 516 Advanced Mechatronics
- MEAM 520 Robotics and Automation (with a laboratory component)
- MEAM 529 RF MEMS and NEMS
- MEAM 535 Advanced Dynamics
- MEAM 550 Micro-Electro-Mechanical Systems
- MEAM 564 (EE 564) The Principles and Practice of Microfabrication Technology
- MEAM 613 Nonlinear Control Theory
- MEAM 620 Robotics
- MEAM 625 Haptic Interfaces

**Preapproved Electives Requirement Courses**

Any graduate level MEAM course

- ESE 500 Linear Systems Theory
- ESE 519 Computer Vision and Computational Photography
- ESE 525 Nanometer Scale Science & Engineering
- CIS 510 Curves & Surface: Theory & Appl.
- CIS 520 Machine Learning
- CIS 580 Machine Perception Development
- IPD 501 Integrated Computer Aided Design
List of approved courses for students concentrating in

HEAT TRANSFER, FLUID MECHANICS, AND ENERGY SCIENCE AND ENGINEERING

Aerospace engineering, materials fabrication and manufacturing, cooling of microelectronic equipment, energy conversion and power generation, and thermal control and treatment of living organisms are critically important in today’s economy. Our program in heat transfer, fluid mechanics, and energy is designed to provide the basic tools for dealing with these and other problems of current and future technological interest. The program maintains close collaboration with the departments of Chemical Engineering, Bioengineering, Electrical and Systems Engineering, and Materials Science.

Preapproved Core Requirement Courses

- MEAM 502 Energy Engineering
- MEAM 504 Tribology
- MEAM 527 Finite Element Analysis
- MEAM 530 Continuum Mechanics
- MEAM 545 Aerodynamics
- MEAM 561 Thermodynamics I
- MEAM 570 Introduction to Transport
- MEAM 571 Advanced Transport
- MEAM 572 Micro/Nano Energy Transport
- MEAM 575 Micro and Nano Fluidics
- MEAM 561 Thermodynamics
- MEAM 642 Fluid Mechanics I
- MEAM 644 BioTransport: Fluid Mechanics, Heat and Mass Transfer
- MEAM 646 Computational Mechanics
- MEAM 647 Foundations of Complex Fluids

Preapproved Electives Requirement Courses

Any graduate level MEAM course

- CBE 520 Modeling, Simulations, and Optimization of Chemical Processes
- CBE 545 Elec. Energy Conv. & Storage
- CBE 617 Control of Nonlinear Systems
- CBE 618 Advanced Molecular Thermodynamics
- CBE 640 Transport Processes I
- CBE 641 Transport Processes II
- CPLN 554 Environmental Management and Evaluation
- CPLN 719 Environmental and Energy Planning Challenges for Cities
- EAS 501 Energy and Its Impacts
List of approved courses for students concentrating in MECHANICS OF MATERIALS

The development of new technologies often depends critically on the availability of materials systems capable of withstanding extreme thermomechanical loading conditions. Current examples are provided by the development of advanced engines in the aerospace industry and the design of microchips that are resistant to thermal cycling in the microelectronics industry. In addition, new technologies, such as biomedical technologies, often require the development and understanding of completely new classes of materials systems. The Penn MEAM MSE in Mechanics of Materials is designed to provide the fundamental tools needed to tackle these and other problems of current and future technological interest. These include basic courses in continuum mechanics, elasticity, and plasticity, as well as more advanced ones in fracture, composite materials, biomechanics, and atomistic modeling of materials. The program maintains close collaborations with the Material Science Department and with the bio-medical community.

Preapproved Core Requirement Courses

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAM 504</td>
<td>Tribology</td>
</tr>
<tr>
<td>MEAM 519</td>
<td>Introduction to Elasticity</td>
</tr>
<tr>
<td>MEAM 530</td>
<td>Continuum Mechanics</td>
</tr>
<tr>
<td>MEAM 537</td>
<td>Nanomech &amp; Nanotribology</td>
</tr>
<tr>
<td>MEAM 554</td>
<td>Mechanics of Materials</td>
</tr>
<tr>
<td>MEAM 555</td>
<td>Nanoscale Systems Biology</td>
</tr>
<tr>
<td>MEAM 631</td>
<td>Advanced Elasticity</td>
</tr>
<tr>
<td>MEAM 632</td>
<td>Plasticity</td>
</tr>
<tr>
<td>MEAM 633</td>
<td>Fracture Mechanics</td>
</tr>
<tr>
<td>MEAM 634</td>
<td>Rods &amp; Shells</td>
</tr>
<tr>
<td>MEAM 635</td>
<td>Composite Materials</td>
</tr>
<tr>
<td>MEAM 663</td>
<td>Entropic Forces in Biomechanics</td>
</tr>
</tbody>
</table>

Preapproved Electives Requirement Courses

Any graduate level MEAM course

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>BE 645</td>
<td>Biological Elasticity</td>
</tr>
<tr>
<td>EAS 504</td>
<td>Fundamental Concepts of Nanotechnology</td>
</tr>
<tr>
<td>MSE 550</td>
<td>Mechanical Properties of Nano and Macro-Scale Materials</td>
</tr>
<tr>
<td>MSE 660</td>
<td>Atomistic Modeling in Materials Science</td>
</tr>
</tbody>
</table>
List of approved courses for students concentrating in **BIOMECHANICS**

Research in Biomechanics spans from the molecular level through to tissue-level investigations, with major efforts in cell mechanics and biophysics, biomolecular simulation, gravity effects on cells and tissues, tendon and ligament injury, repair, regeneration, and intervertebral disc function/degeneration, and targeted drug delivery.

**Preapproved Core Requirement Courses**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAM 527</td>
<td>Finite Element Analysis</td>
</tr>
<tr>
<td>MEAM 554</td>
<td>Mechanics of Materials</td>
</tr>
<tr>
<td>MEAM 555</td>
<td>Nanoscale Systems Biology</td>
</tr>
<tr>
<td>MEAM 570</td>
<td>Introduction to Transport Phenomena</td>
</tr>
<tr>
<td>MEAM 663</td>
<td>Entropic Forces in Biomechanics</td>
</tr>
<tr>
<td>MEAM 635</td>
<td>Composite Materials</td>
</tr>
<tr>
<td>MEAM 642</td>
<td>Fluid Mechanics I</td>
</tr>
</tbody>
</table>

**Preapproved Electives Requirement Courses**

Any graduate level MEAM course

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
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<tr>
<td>BE 512</td>
<td>BIO III - Biomaterials</td>
</tr>
<tr>
<td>BE 513</td>
<td>Cell Biology</td>
</tr>
<tr>
<td>BE 553</td>
<td>Principles, Methods, and Applications of Tissue Engineering</td>
</tr>
</tbody>
</table>

Graduate course in the BioSciences
List of approved courses for students concentrating in

**DESIGN AND MANUFACTURING**

Global business trends have created a demand for companies to rapidly develop new products at lower costs. In response to these demands companies have been exploring new methods to decrease costs, increase productivity, and create innovative products. In keeping with the needs of local industry the graduate courses below prepare students for careers in Product Design and Manufacturing. Students in the program will study topics such as mechatronics, CAD, computer graphics, industrial design, product design, materials engineering, manufacturing processes, assembly, tolerances, design analysis, plant/process modeling and design, robotics, electrical systems, mechanical systems, controls, intellectual property, and management skills. Graduates of the program will be prepared to be leaders in global manufacturing environment. Much of our work involves collaborations with, among others, the Departments of Computer and Information Science, Electrical and Systems Engineering as well as the School of Design and the Wharton School of Business Administration.

**Preapproved Core Requirement Courses**

- MEAM 510 Mechatronics
- MEAM 514 Design for Manufacturability
- MEAM 516 Advanced Mechatronics
- MEAM 527 Numerical and Finite Element Methods
- MEAM 504 Tribology
- MEAM 537 (MSE 537) Nanomechanics and Nanotribology at Interfaces
- MEAM 540 Optimal Design of Mechanical Systems
- MEAM 550 Micro-Electro-Mechanical Systems
- MEAM 625 Haptic Interfaces

**Preapproved Electives Requirement Courses**

Any Graduate Level MEAM course

- ARCH 722 Furniture Design
- CIS 510 Curves & Surface: Theory & Applications
- CIS 560 Computer Graphics
- IPD 501 Integrated Computer Aided Design
- IPD 511 Creative Thinking and Design
- IPD 515 Product Design
- IPD 527 Industrial Design I
- OPIM 654 Product Design and Development
- OPIM 655 Integrated Marketing and Operations
APPENDIX B

Hard Cover Instructions
for MSE Theses

Guidelines:

In addition to the unbound copies that must be given to the Office of the Associate Dean for Graduate Education and Research, one hardbound copy of each MSE thesis must be submitted to the Graduate Group Chair and one hardbound copy must be submitted to the student's advisor.

There is a charge of $25.00 per copy. Please check with the Graduate Program Coordinator for more information about hard binding your thesis or dissertation.

MSE dissertations are to be bound in a black cover with gold letters.

The lettering on the front should look like the following example:

Alfred E. Neuman

Design Optimization and Control of a Multi-robot System to Study the Size-Dependent Effects in the Mechanics of Muscle Cells Flowing Through Heated Micro Conduits

MSE Theses
Mechanical Engineering and Applied Mechanics
University of Pennsylvania
2011
APPENDIX C
GRADUATE TRANSFER OF CREDIT PETITION

TO: SEAS Associate Dean for Academic Affairs

FROM:  

Name of Student  

PENN ID #:  

DEPT:  

DATE:  

Include with this petition, course numbers and descriptions from the appropriate bulletin listing and a final transcript. A maximum of two courses may be transferred to the Master's program or a maximum of nine to the Ph.D. program if approved. Courses counted towards an undergraduate degree will not be considered for graduate credit unless in an approved submatriculation program.

TRANSFER OF CREDIT TO:  

☐ Master’s program  

☐ Ph.D. program  

FROM WHICH UNIVERSITY:  

Please list courses to be transferred and SEAS equivalent if applicable:

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Adviser's Approval  

Date  

☐ Approved  

☐ Disapproved  

Graduate Group Chairman  

Date  

Associate Dean for Academic Affairs  

Date
APPENDIX D

MEAM Graduate Group Members

Paulo E. Arratia (parratia@seas.upenn.edu), Assistant Professor. Micro- and nano-fluidics, complex fluids, hydrodynamic instabilities, swimming & locomotion, rheology, and soft-condensed matter.

P. S. Ayyaswamy (ayya@seas.upenn.edu), Asa Whitney Professor of Dynamical Engineering. Phase change heat and mass transfer processes, bioheat/mass transfer: gas embolism, targeted drug delivery, and arc-plasma heat transfer.

John L. Bassani (bassani@seas.upenn.edu), Richard H. and S. L. Gabel Professor of Mechanical Engineering. Plastic deformation of crystals, atomic/continuum property relationships, interface mechanics, fracture mechanics, material stability at large strains, adhesion, mechanics of living cells.

Haim H. Bau (bau@seas.upenn.edu), Professor and Undergraduate Group Chair. Micro and nano fluidics, nanotechnology, real time electron microscope imaging of processes in liquid media, lab on chip technology, diagnostic devices for point of care, and fluid and particle motion under the action of electric and magnetic fields.

Robert W. Carpick (carpick@seas.upenn.edu), Professor and Department Chair. Experimental nanomechanics, nanotribology (contact, friction, adhesion, lubrication, wear), surface science and engineering, and thin films. Development, characterization, and applications of materials and devices at the nanoscale including micro/nanoelectromechanical systems (MEMS/NEMS). Development and application of advanced scanning probe microscopy tools.

Stuart Churchill (churchil@seas.upenn.edu), Carl V. S. Patterson Professor Emeritus of Chemical and Biomolecular Engineering. Combustion, rate processes and correlation, the prediction of turbulent flow and convection.

Dennis E. Discher (discher@seas.upenn.edu), Professor of Chemical and Biomolecular Engineering. Stem cell mechanics, single molecule mechanics, statistical mechanics

David M. Eckmann (David.Eckmann@uphs.upenn.edu), Horatio C. Wood Professor of Anesthesiology & Critical Care. Experimental and computational biofluid dynamics, interfacial fluid mechanics, molecular mechanics of cellular activation and biological adhesion to vascular tissue, biomimetic materials and targeted drug delivery.

Dawn M. Elliott (delliott@mail.med.upenn.edu), Adjunct Professor of Orthopaedic Surgery. Orthopaedic biomechanics of the intervertebral disc; anisotropic, nonlinear, and viscoelastic biomechanics; models of disc degeneration; structure-function of the disc.

Daniel S. Gianola (gianola@seas.upenn.edu), Skirkanich Assistant Professor, Materials Science and Engineering. Nano- and micromechanics of materials, atomic-scale deformation mechanisms, in situ testing using electron microscopy, strain engineering of transport phenomena for efficient energy conversion, materials under extreme environments, experimental techniques for nanoscale materials testing.

Howard H. Hu (hhu@seas.upenn.edu), Professor. Numerical simulations of complex flows with multiphase and polymeric fluids, particulate flows, flows in microfluidic devices, electrophoretic phenomena, hydrodynamic interfacial instability.

Daniel E. Koditschek (kod@seas.upenn.edu), Alfred Fitler Moore Professor and Chair of Electrical and Systems Engineering. Robotics, computational neuromechanics, dynamical systems theory applied to design of intelligent machines and their control.

Katherine J. Kuchenbecker (kuchenbe@seas.upenn.edu), Skirkanich Assistant Professor of Innovation. Haptics for teleoperation, virtual environments, and robotic manipulation, with application to robot-assisted surgery, medical simulation and training, rehabilitation, exploration, design, mobile computing, and education.

Vijay Kumar (kumar@seas.upenn.edu), UPS Foundation Professor and Deputy Dean for Education. Robotics, multi-vehicle control, dynamical systems, systems biology.

Noam Lior (lior@seas.upenn.edu), Professor. Energy conversion, advanced power generation, global warming alleviation, solar energy, sustainable energy and water desalination development and sustainability science, combustion, water desalination, materials processing.
Jennifer R. Lukes (jrlukes@seas.upenn.edu), Associate Professor and Graduate Group Chair. Nanoscale thermal, fluid, and mass transport; molecular dynamics simulation; laser-based materials characterization; field-directed patterning for nanofabrication; micro- and nanoscale engineering.

Robert L. Mauck (lemauck@mail.med.upenn.edu), Associate Professor of Orthopaedic Surgery and Bioengineering. Biomechanics of tissue engineered musculoskeletal tissues, Bioreactor development for mechanical stimulation, Mechanobiology of cells and tissues, Fabrication and modeling of hydrogels and nanofibrous scaffolds.

Charles J. McMahon, Jr. (cmcmahon@lrsrn.upenn.edu), Professor Emeritus, Materials Science and Engineering. Mechanisms of intergranular embrittlement and fracture in high-strength structural materials, especially as related to environmental effects. Current interests are dynamic embrittlement in nickel and copper-based alloys and in steels.

George J. Pappas (pappasg@grasp.upenn.edu), Joseph Moore Professor of Electrical and Systems Engineering and Deputy Dean for Research. Hybrid systems, hierarchical control systems, embedded systems, nonlinear systems, geometric control theory, robotics, unmanned aerial vehicles.

Gianluca Piazza (piazza@seas.upenn.edu), Assistant Professor of Electrical and Systems Engineering. Micro/nanoElectroMechanical systems (MEMS/NEMS), piezoelectric materials, wireless transducers, sensors and actuators, biochemical detectors, micro/nanofabrication techniques.

Pedro Ponte Castañeda (ponte@seas.upenn.edu), Professor. Nonlinear composite and polycrystalline materials, smart materials, microstructure evolution and localization in manufacturing processes, mechanics of polymers, fracture mechanics, nonlinear variational principles in mechanics.

Prashant Purohit (purohit@seas.upenn.edu), Assistant Professor. Rod theories for DNA and biopolymers, mechanics of subcellular organelles, mechanics at the bio-nano interface, martensitic phase transitions in solids.

Talid R. Sinno (talid@seas.upenn.edu), Associate Professor of Chemical and Biomolecular Engineering. Computational materials science, multiscale modeling and simulation, nucleation and aggregation phenomena in electronic materials and complex fluids.

Louis J. Soslowsky (soslowsk@mail.med.upenn.edu), Fairhill Professor of Orthopaedic Surgery and Professor of Bioengineering and Director of Penn Center for Musculoskeletal Disorders. Orthopaedic biomechanics and functional tissue engineering; structure-function studies of tendons and ligaments; models of tendon injury, repair, and healing; shoulder joint mechanics.

Camillo J. Taylor (cjtaylor@central.cis.upenn.edu), Associate Professor of Computer and Information Science. Reconstructing and rerendering 3D scenes from 2D images and vision guided robotic systems.

Kevin T. Turner (kturner@seas.upenn.edu), Associate Professor, Gabel Family Term Junior Professor of Mechanical Engineering. Micro/nanoscale manufacturing processes, experimental and computational fracture and contact mechanics, small-scale adhesion mechanics, micro/nanoelectromechanical systems, mechanics of biological interfaces and cells.

Karl T. Ulrich (ulrich@wharton.upenn.edu), CIBC Professor of Operations and Information Management (Wharton School). Product design, product development, innovation, technology development, personal transportation, environmental issues.

Vaclav Vitek (vitek@lrsrn.upenn.edu), Professor of Materials Science and Engineering. Computer modeling of the structure and properties of grain boundaries, metal-metal and metal-ceramic interfaces, dislocations and other lattice defects.

Beth A. Winkelstein (winkelst@seas.upenn.edu), Professor of Bioengineering and Neurosurgery. Spine biomechanics; modeling & experimental methods in subfailure mechanics; joint mechanics; mechanical modulation of pain and cellular dysfunction; models of ligament & nerve injury.

Mark Yim (yim@grasp.cis.upenn.edu), Professor and Director of Integrated Product Design. Modular self-reconfigurable robotics, virtual reality (haptics), meso-scale devices (typically larger than MEMS).
APPENDIX E

Mechanical Engineering and Applied Mechanics
Worksheet for Course Registration

Name: ________________________________________________________________

Year Matriculated:_____ Degree program:______ (PhD/MSE) Status: ________(Full-time/Part-time)

Concentration Area: ________________________________

Proposed Thesis Topic and/or Title (if applicable):

PROPOSED COURSES OF STUDY FOR (TERM/s) ______ and ______

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Additional notes (if any):

________________________________________ ____________________________

________________________________________ ____________________________

________________________________________ ____________________________

Student’s Signature ___________________ Date ______________

Required only for first-year Masters and PhD students

“I have met with the student and discussed the course plan for the term(s) indicated above.”

Advisor’s Signature ___________________ Date ______________
### Faculty Section Numbers

MEAM 899 (PhD Independent Study) / 999 (PhD Research) Section Numbers

597 (MSE Thesis Research) / 599 (MSE Independent Study)

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